Controversial findings help explain evolution of life

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Chemists at Oregon State University have pioneered a controversial theory about how supposedly-stable DNA bases can be pushed into a "dark state" in which they are highly vulnerable to damage from ultraviolet radiation – an idea that has challenged some of the most basic concepts of modern biochemistry.

The theory, not long ago dismissed as impossible by much of the science community, has just in recent months begun to garner increasing interest, and is being confirmed by other studies.

And though it began as scientific heresy, the findings could help explain how the presence of water was the key to the evolution of life on Earth, making it possible for life to emerge from what was once a hostile and unforgiving primordial soup of chemicals and radiation.

More and more research is being focused on this area since a study proving the existence of this "dark state" was published by OSU researchers in the Journal of Physical Chemistry – even though other journals had repeatedly rejected the findings because they were too radical.

"The findings of our studies did not fit most people's preconceived notions about how DNA molecules work, so they assumed we had to be wrong," said Wei Kong, an OSU professor of chemistry. "The critics seemed very sure of themselves, and we had a lot of sleepless nights."

"But just since last summer this has been a key point of discussion at several conferences and caused quite an excitement, as people see the data," Kong said. "Among other things, it helps to explain how water, or something else serving the same role, could have helped lead to the evolution of life."

The core of the debate, Kong said, relates to the behavior of the nucleic acid bases – adenine, thymine, guanine and cytosine - that as A-T and G-C base pairs form DNA and ultimately become the blueprint for all living things. One of the most basic premises of biochemistry is that these nucleic acid bases are very stable, as they would have to be to prevent rampant mutations and make an organized genetic structure possible.

But studies at OSU, which were done with highly sophisticated electron spectroscopy, showed that the alleged stability of the nucleic acid bases in DNA is largely a myth.

"In their biological form, surrounded by other hydrogen-bonded bases, it's true that the nucleic acids which make up DNA are stable," Kong said. "But we found that living things, in their totality, provide an environment which creates that stability, through attachments within base pairs and/or with neighboring bases. These attachments allow damaging photonic energy to be released as heat. But a DNA base as an isolated molecule, just by itself, does not have that stability."

In a compelling experiment, OSU scientists probed the fate of nucleic acid bases after laser irradiation in the ultraviolet range. They found that the molecules – which react extraordinarily fast to ultraviolet light insults – could by themselves spend 20-300 nanoseconds in an unstable, vibrating "dark state" in which they could easily mutate and not fully recover from photonic damage.

The lifetime of the dark state is not long – a nanosecond is one billionth of a second. But it's more than enough time for DNA mutations to happen, Kong said. And the existence of this dark state raised questions about how life ever could have begun, given that the genetic carriers were so easily mutated or destroyed during this very brief but very vulnerable time.

"When the bases of DNA were first being formed billions of years ago, the atmosphere was actually quite hostile," Kong said. "It was a period prior to any protective ozone layer on Earth and the ultraviolet radiation was very strong. So if primordial DNA bases were forced into this vulnerable dark state, they should have incurred large amounts of photochemical damage that would have made the very survival of these bases difficult, let alone further evolution of life."

Except for one other finding, that is.

According to OSU research, the "dark state" essentially disappears in the presence of water. So if water were present, the earliest DNA bases would have been able to survive and eventually help form the basis for ever-more-complex life forms.

"In modern biological forms, it's not essential that water be present for DNA to have stability," Kong said. "There are other mechanisms that now exist in biology to accomplish that, and complex biological processes are possible that don't always require water. But in its most basic form, we now know that DNA bases are not stable and they are highly vulnerable to UV-induced damage."

The findings suggest, Kong said, how water could have been an absolutely essential compound to allow early DNA bases to remain stable, resist mutation, and ultimately allow for the evolution of life.

OSU researchers were the first to propose the "dark state" model and prove its existence.

"What this is really telling us is that life is a unified process," Kong said. "It's not just a group of DNA bases, but it's also the physical environment in which they exist. Later on, as life became more evolved, there were other ways to achieve genetic stability. But at first, it simply may not have been possible without water."

Source: Oregon State University